3/PRTS

10/525072

DT05 Rec'd PCT/PTO 18 FEB 2005

~~METHOD AND~~ APPARATUS FOR MODIFYING A ~~RADIO FREQUENCY~~ RESPONSE

BACKGROUND

Field

[0001] The present invention relates generally to a method and apparatus for modifying a radio frequency response.

Background Information

[0002] Millimeter wave seekers and advanced radio frequency (RF) concepts have used broadband and agile waveforms in space constrained packages. Dynamically tunable devices have been used to support these waveforms. Broadband and frequency agile systems have used switched banks of RF devices to support the radar waveforms.

SUMMARY

[0003] The present invention is directed to a method, and associated apparatus, for modifying a radio frequency (RF) response, comprising: establishing an RF response in a signal path of a device; and controlling an actuator to structurally alter the signal path and dynamically change an impedance of the signal path to alter the RF response.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Other objects and advantages will become apparent to those skilled in the art upon reading the following detailed description of preferred embodiments, in conjunction with the accompanying drawings, wherein like reference numerals have been used to designate like elements, and wherein:

[0005] Figure 1 shows an exemplary apparatus for modifying a radio frequency response.

[0006] Figure 2 shows three exemplary frequency responses.

[0007] Figure 3 shows an exemplary use of an undercut post complementary metal oxide semiconductor (CMOS) processing.

[0008] Figures 4a-4c illustrate exemplary uses of MEMS actuators.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] A method and apparatus for modifying a radio frequency (RF) response are disclosed. For example, the RF response can be the transfer function of a signal path of, for example, a filter, a phase shifter, an attenuator or other device, that is to be modified. An exemplary method includes establishing an RF response in the signal path of a device, and controlling an actuator to structurally alter the signal path and dynamically change an impedance of the signal path to alter the RF response.

[0010] The method can be implemented using an apparatus such as that of Figure 1. The Figure 1 apparatus 100 includes a signal path 102 having an RF transfer function. The signal path can be implemented using any conductive material including, but not limited to, any metallization layers formed among a dielectric 106 (e.g., dielectric layers) using, for example, a suitable CMOS process. The dielectric can, for example, be polysilicon. Those skilled in the art will appreciate that any forming process can be used to produce the Figure 1 application including both silicon and non-silicon processes in conjunction with formation of metallization layers using any known techniques. The Figure 1 device can be configured to have

dimensions in a range on the order of 10 microns to 100 microns, or larger or smaller as determined by the application.

[0011] The Figure 1 apparatus 100 includes an in situ (i.e., formed in the apparatus) actuator, such as a microelectromechanical system (MEMS) actuator, for tuning the device by changing the RF transfer function of the signal path 102. For example, operating parameters of the RF signal path can be changed dynamically by post machining sections of CMOS circuit elements to create the MEMS actuator. The actuator can thus be controlled to structurally, or mechanically, alter the signal path (i.e., alter physical characteristics) and dynamically change an impedance of the signal path to alter the RF response. That is, the dynamic change occurs in response to external excitation (such as thermal, electrical, or other excitation), whereby the MEMS actuator can be controlled, or adjusted, to structurally change the signal path, and thus alter electrical parameters (such as coupling capacitance, inductance, and so forth) of a transfer function of the signal path, and of the apparatus. A frequency, phase and/or amplitude of a signal received along a signal path can thereby be modified.

[0012] Referring to Figure 1, the signal path 102 is shown to be configured using plural segmented, conductive legs 104a-104f used to form a segmented path, having cascaded legs, wherein coupling coefficients of the cascaded legs are altered using an actuator. The conductors 104a-104f, in an exemplary embodiment, constitute fixed point portions of a signal path (i.e., portions of the signal path which remain fixed within the dielectric 106). A second set of one or more conductors 105a-105c are formed in proximity to the fixed point conductors of the signal path 102 to alter the coupling coefficients. A portion of the dielectric 106 can be partially etched in a vicinity of each of the conductors 105a-105c to accommodate their movement of the conductors 105a-105c (e.g., vertical movement in the orientation of the Figure 1 illustration).

[0013] For example, referring to Figure 1, the arrow 108 illustrates a controlled movement of the conductor 105a among three different positions. Similarly, an

arrow 110 illustrates a controlled movement of the conductor 105c among three different positions. By selectively, and dynamically, moving any one or more of the conductors 105a-105c among any number of available positions, the impedance of the signal path 102 can be altered, thereby altering the transfer function of the signal path and changing a response of the signal path.

[0014] For example, Figure 2 illustrates three different frequency responses which can be achieved using a common signal path, wherein positions of conductors such as conductors 105a-105c, have been dynamically relocated. Thus, a filter having a varied transfer function can be obtained.

[0015] Figure 3 shows an exemplary use of CMOS processing, or more particularly, an undercut post CMOS processing, to achieve a suspended beam of conductive material (i.e., suspended relative to an anchor post), that can serve to form any one or more of the dynamically movable conductors 105a-105c.

[0016] Figures 4a-4c illustrate the use of MEMS actuators to achieve lift, lateral movement and rotation, respectively, of a conductor for altering characteristics of a signal path in accordance with exemplary embodiments Of course, any type of motion that can be used to alter characteristics of the signal path can be incorporated into a structure designed in accordance with exemplary embodiments.

[0017] In accordance with exemplary embodiments, movement of the legs of each of the segments 105a-105c in Figure 1 can be performed to empirically and statistically measure a resultant transfer function for each given position of the legs, such that a given movement of the conductors can be correlated to a desired response.

[0018] Exemplary embodiments can provide performance enhancement by, for example, reducing size and costs. Exemplary embodiments can use post processing of RF circuits developed using known CMOS technology to fabricate MEMS actuator RF devices. Operating parameters of an RF circuit element can be changed dynamically by post machining sections of CMOS circuit elements to form (i.e., create) the MEMS actuator. Under external excitation (e.g., thermal, electrical or

otherwise), the MEMS actuator can dynamically move to change electrical parameters (e.g., coupling capacitance, inductance and so forth), which can change a transfer function of the RF device. This can result in changes of the passband response for a filter, coupling values for dividers, magnitude response for attenuators and so forth. Exemplary applications can include missile seekers, fire control radar, communications systems UAV sensors, and so forth.

[0019] It will be appreciated by those skilled in the art that the present invention can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the invention is indicated by the appended claims rather than the foregoing description and all changes that come within the meaning and range and equivalence thereof are intended to be embraced therein.